Chihuahuan Desert Network
Water Resource Information and Assessment Report
Phase II

By

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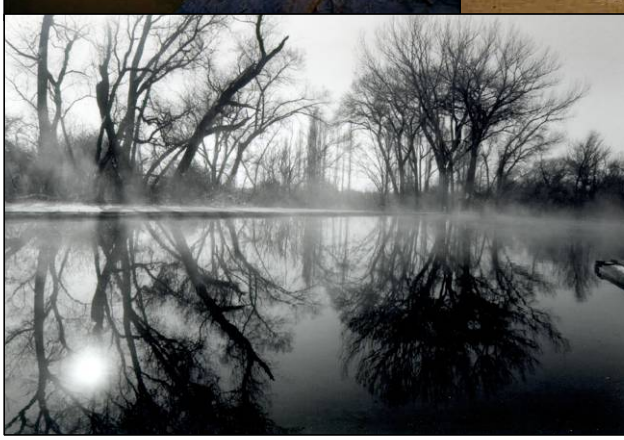


18 September 2006

Suggested Citation:

Huff, G. F.[1], M. H. Reiser[2], and J. T. Richie[2]. 2006. Chihuahuan Desert Network Water Resource Information and Assessment Report, Phase II. National Park Service, Chihuahuan Desert Network, Las Cruces, NM, USA.

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Cover Photos: Chihuahuan Desert Network Waters. Clockwise from upper left: Santa Elena Canyon in Big Bend NP (© Mark Abraham by permission), Lake Lucero Playa at White Sands NM, Amistad Reservoir at Amistad NRA, Winter morning fog at Rattlesnake Springs, Carlsbad Caverns NP.

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Executive Summary

The Chihuahuan Desert Inventory and Monitoring Network (CHDN) of the National Park Service is tasked with the inventory and monitoring of natural resources, including biologic, geologic, and water resources within seven park units in New Mexico and Texas. Park units within the CHDN include Amistad National Recreation Area, Big Bend National Park, Carlsbad Caverns National Park, Fort Davis National Historic Site, Guadalupe Mountains National Park, the Rio Grande Wild and Scenic River, and White Sands National Monument. The goals of inventory and monitoring activities are to: 1) determine the status of, and trends in, selected vital signs, 2) provide early warning of 'abnormal' conditions, 3) provide data to better understand the dynamic nature and conditions of natural resources, 4) provide data to meet legal mandates, and 5) provide a means of measuring progress toward performance goals.

Vital signs include a set of factors that indicate the status of park resources, represent the effects of environmental stressors, or represent important human values. Water-resource vital signs were identified for CHDN surface-water and groundwater resources through participation of government and academic water-resources experts in a series of workshops and web-based surveys. Water-resource vital signs identified for the CHDN include:

1. surface water quality as determined by temperature, pH, specific conductance, turbidity, abundance of bacteria, abundance and diversity of macroinvertebrates, and concentrations of common dissolved inorganic constituents, dissolved oxygen, nutrients, and concentrations of selected anthropogenic organic compounds;

2. rates and frequencies of surface-water discharge;

3. lake and reservoir levels (Amistad National Recreation Area and White Sands National Monument only);

4. sediment load and chemical composition;

5. groundwater quality as determined by temperature, pH, specific conductance, concentrations of common dissolved inorganic constituents, and concentrations of selected anthropogenic organic compounds; and

6. groundwater levels.

Not all vital signs are equally applicable to all CHDN park units.

Past and current water-resources monitoring within and near CHDN park units include measurement of surface-water and groundwater quality and

quantity by entities including individual parks within the CHDN, the International Boundary and Water Commission, the New Mexico Office of the State Engineer, the Texas Water Development Board, the Texas Commission on Environmental Quality, and the U.S. Geological Survey. As a result of this monitoring, surface-water quality within and near CHDN units has been determined to exceed applicable water-quality standards in Texas Stream Segments 2304, 2305, 2306, 2307, and 2310. Park units affected by these exceedances include Amistad International Reservoir (Texas Stream Segments 2305 and 2310), and Big Bend National Park and the Rio Grande Wild and Scenic River (Texas Stream Segment 2306). Water quality exceeding the requirements for impairment (as defined by Section 303d of the Clean Water Act) has been identified in Texas Stream Segments 2304, 2305, and 2307. The park unit affected by these impairments is Amistad International Reservoir (Texas Stream Segment 2305).

Selected protocols for the measurement of water-resource factors, developed and documented by the U.S. Geological Survey, are identified for consideration in the development of a CHDN monitoring plan. Selected protocols include measuring groundwater levels, sampling for groundwater quality, selecting water quality sampling equipment, general guide to collection of water quality samples, processing of water quality samples, measuring field characteristics (temperature, pH, specific conductance, and dissolved oxygen), measuring biological indicators, collecting of biological samples, sampling of bottom materials (sediment), continuous monitoring of water quality, stage measuring at stream-gaging stations, measuring discharge ratings at stream-gaging stations, computing stream flow records, determining elevations at stream-gaging stations, measuring fluvial sediment, and computing fluvial sediment discharge.

1 Introduction

The Chihuahuan Desert Inventory and Monitoring Network (CHDN) of the National Park Service (NPS) is tasked with the inventory and monitoring of natural resources including biologic, geologic, and water resources within seven park units in New Mexico and Texas. Park units within CHDN include Amistad National Recreation Area (AMIS), Big Bend National Park (BIBE), Carlsbad Caverns National Park (CAVE), Fort Davis National Historic Site (FODA), Guadalupe Mountains National Park (GUMO), the Rio Grande Wild and Scenic River (RIGR), and White Sands National Monument (WHSA) (Figure 1.1). Inventory will be made through systematic measurement of environmental indicators known as "vital signs." Vital signs indicate the status of park resources, represent the effects of environmental stressors, or represent important human values.

Figure 1.1 Location of park units within the Chihuahuan Desert Inventory and Monitoring Network.

Monitoring will continue the efforts of inventory by systematic measurement of vital signs. The goals of inventory and monitoring activities are to: 1) determine the status of, and trends in, selected vital signs, 2) provide early warning of 'abnormal' conditions, 3) provide data to better understand the dynamic nature and condition of natural resources, 4) provide data to meet legal mandates, and 5) provide a means of measuring progress toward performance goals.

1.1 Purpose and Scope

This report discusses: 1) past and current water-resources monitoring within and near CHDN park units and identifies constituents in surface water that exceed applicable water quality standards, 2) the processes and criteria used to identify, prioritize, and select water-resources vital signs; 3) the selection of water-resources vital signs that accomplish the goals of inventory and monitoring; and 4) protocols for measurement of environmental indicators identified as water-resources vital signs for CHDN park units.

1.2 Description and Hydrologic Setting

Park units within the CHDN are located within a variety of natural and man-made hydrologic settings. A brief description of each park unit within the CHDN is given below; park unit areas are shown in Table 1.1.

Table 1.1 List of park units in the Chihuahuan Desert Network.

Unit	State	Park Code	Hectares	Acres
Amistad National Recreation Area	TX	AMIS	23,186	57,292
Big Bend National Park	TX	BIBE	324,226	801,163
Carlsbad Caverns National Park	NM	CAVE	18,926	46,766
Fort Davis National Historic Site	TX	FODA	192	474
Guadalupe Mountains National Park	TX	GUMO	34,972	86,416
Rio Grande Wild and Scenic River*	TX	RIGR	2,090	5,164
White Sands National Monument	NM	WHSA	58,168	143,733
		Total	461,760	1,141,008

***** RIGR encompasses 315 river km (196 river miles) from the Chihuahua-Coahuila State line in Mexico to the Terrell Val Verde County Line in the United States. Though for planning purposes and project implementation, the BIBE-RIGR overlap is considered and is limited to the 209 river km (127 river miles) between Big Bend and the Terrell-Val Verde County line.

The principal feature of AMIS is the International Amistad Reservoir created by damming of the Rio Grande in 1969 (Figure 1.2). AMIS contains, on average, 17,503 hectares (ha) (43,250 acres) of inundated land and 5,683 ha (14,042 acres) of dry land. The predominant surface-water drainage is from surrounding areas toward the International Amistad Reservoir. Riparian, shoreline, inundated zone, and arid to semi-arid desert zones exist within the border of AMIS.

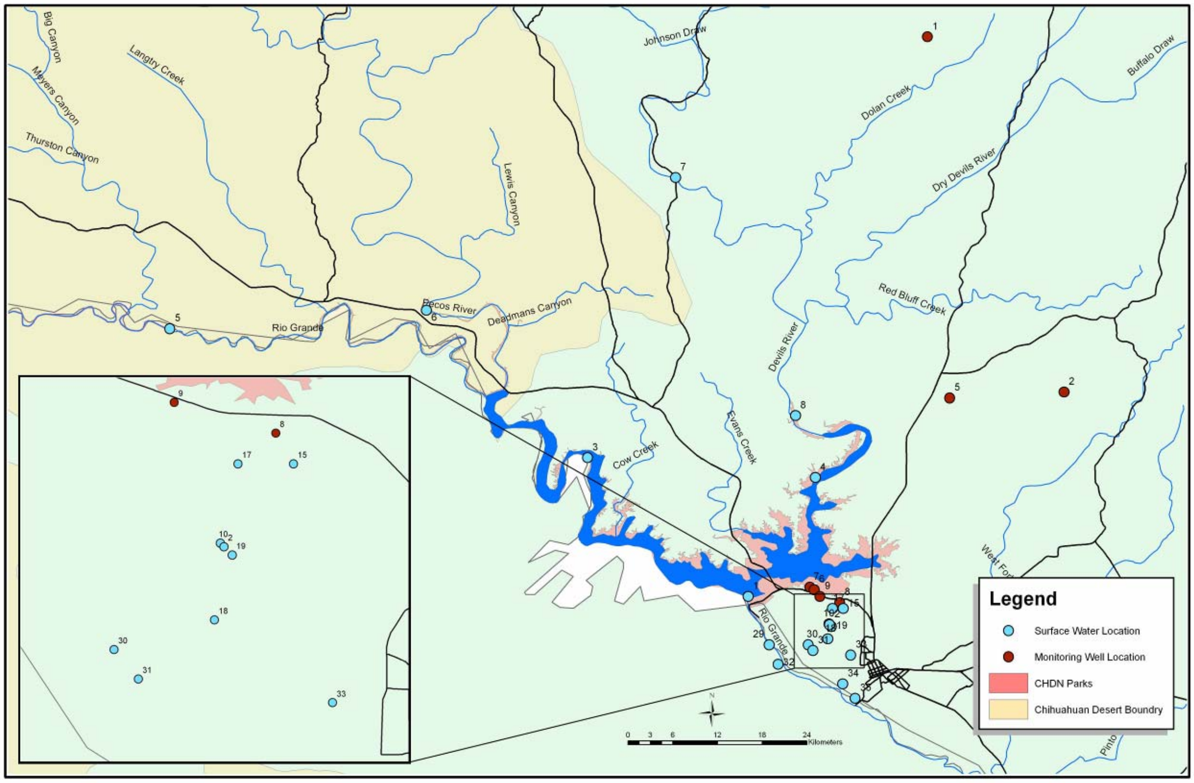

Figure 1.2 Surface- and groundwater monitoring locations within and near Amistad National Recreation Area (location numbers refer to Appendix A and B).

Established in 1944, BIBE covers 216,066 ha (801,163 acres) of the Chihuahuan Desert in southernmost Texas (Figure 1.3). The southwestern, southern, and southeastern boundaries of BIBE coincide with reaches of the Rio Grande that define, in part, the border between the United States and Mexico. Surface-water drainage is typically from BIBE into surrounding areas, except in some northern areas of the park. More than 300 springs were documented by surveys within BIBE in 1986 and 1990 (NPS, 1992). Springs contribute a substantial amount of discharge in the Rio Grande along the BIBE border (J.H. King, NPS, 2005, written communication.)

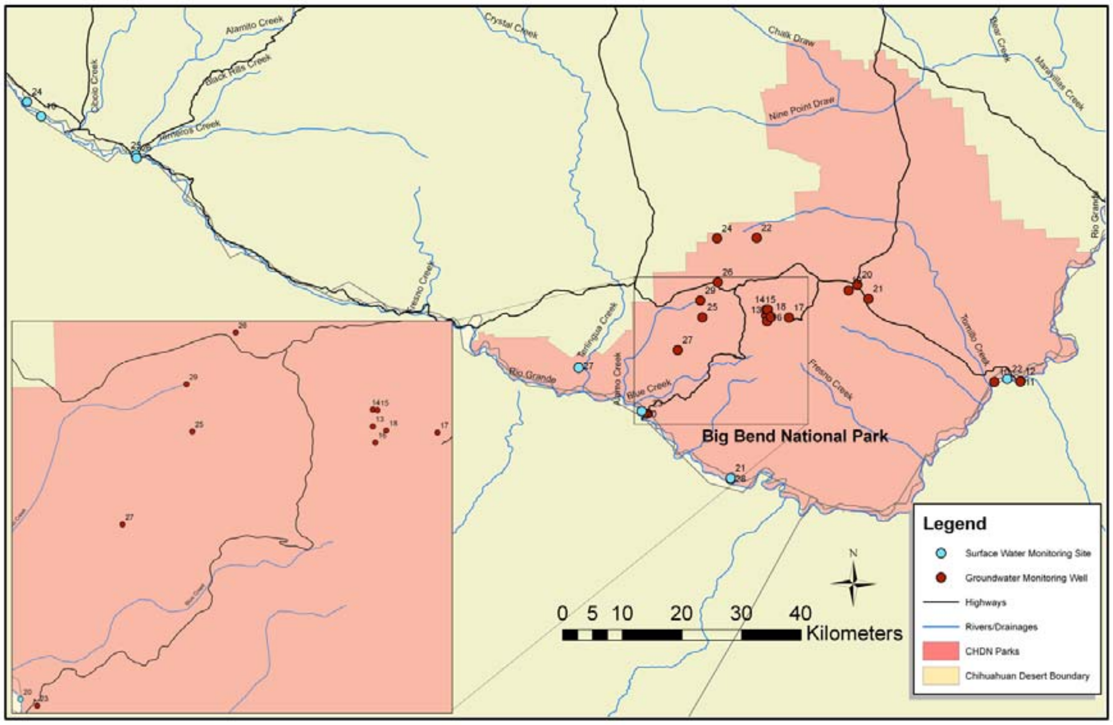

Figure 1.3 Surface-water and groundwater monitoring locations within and near Big Bend National Park (location numbers refer to Appendix A and B).

Established in 1923, CAVE covers 18,926 ha (46,766 acres) of southeastern New Mexico, of which 13,406 ha (33,125 acres) are designated wilderness (Figure 1.4). An important feature of this Park is the existence of more than 80 caves in the Capitan Reef Limestone of Permian age. Many of these caves are hydrologically active and contain perennial pools. Surface-water drainage is predominantly from the park to surrounding areas.

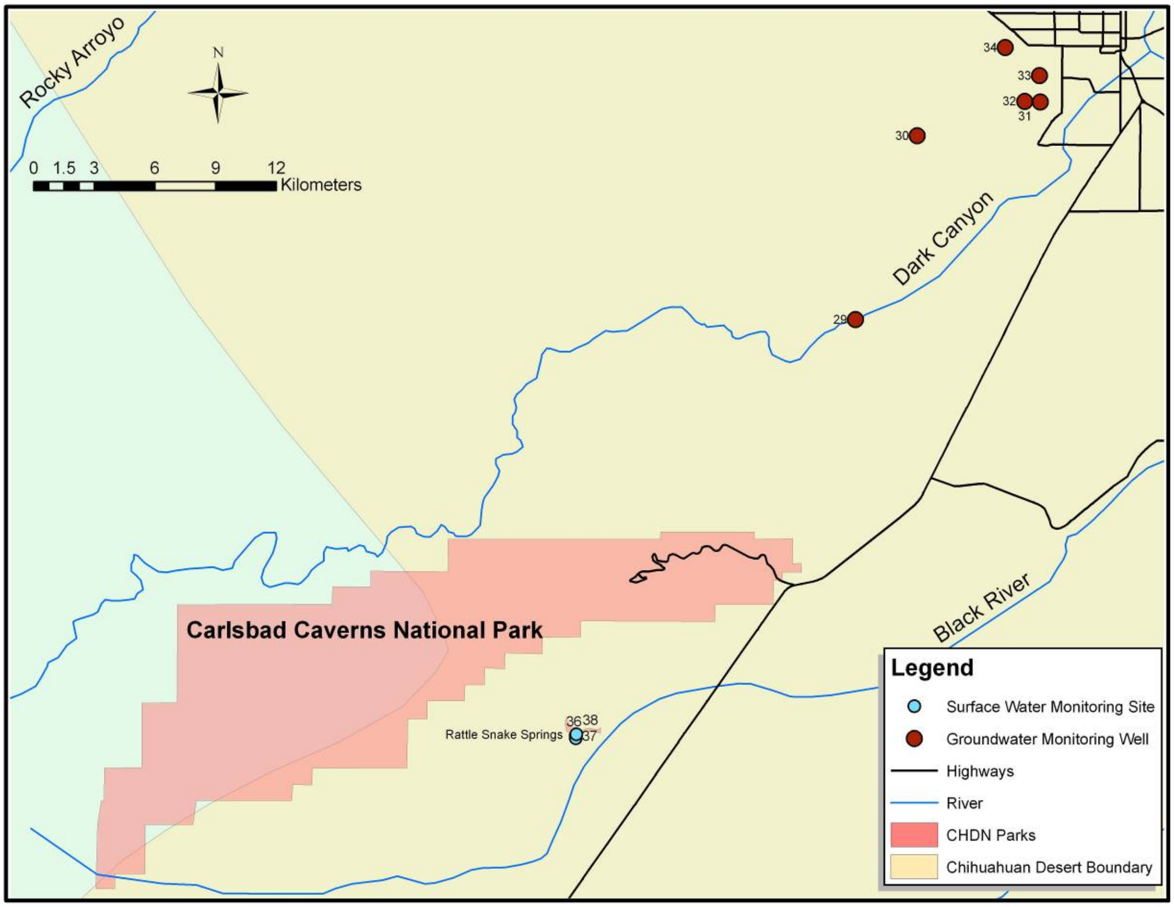

Figure 1.4 Surface-water and groundwater monitoring locations within and near Carlsbad Caverns National Park (location numbers refer to Appendix A and B).

Established in 1963, FODA covers 192 ha (474 acres) of the Davis Mountains in south-central Texas (Figure 1.5). Limpia Creek, which passes along the northern boundary of FODA, is the only prominent body of water associated with the park.

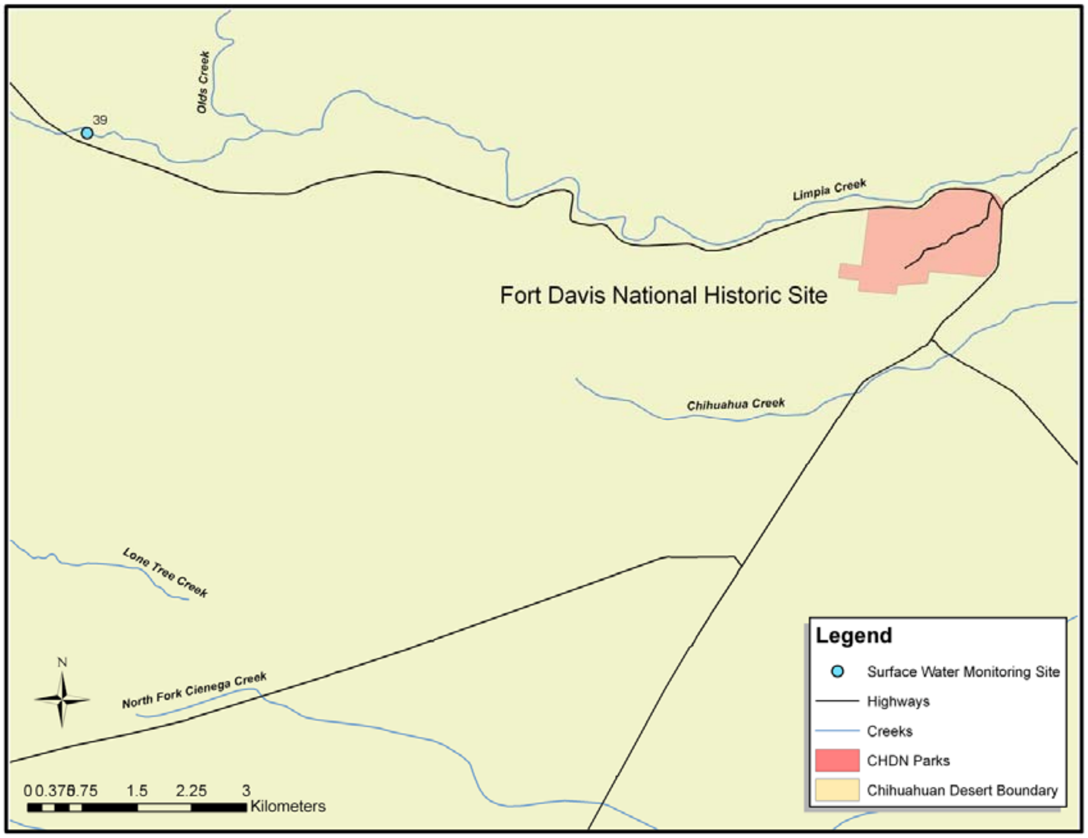

Figure 1.5 Surface-water and groundwater monitoring locations within and near Fort Davis National Historic Site (location numbers refer to Appendix A).

Established in 1972, GUMO covers 34,972 ha (86,416 acres) of the Guadalupe Mountains and surrounding areas, in westernmost Texas. Eighteen thousand nine hundred and sixty (18,960) ha (46,850 acres) of GUMO are designated wilderness (Figure 1.6). Surface-water drainage is predominately from the park to surrounding areas. Substantial groundwater resources are potentially present within the Goat Seep limestone of Permian age near the western margin of the park (Gates et al. 1980, Angle 2001).

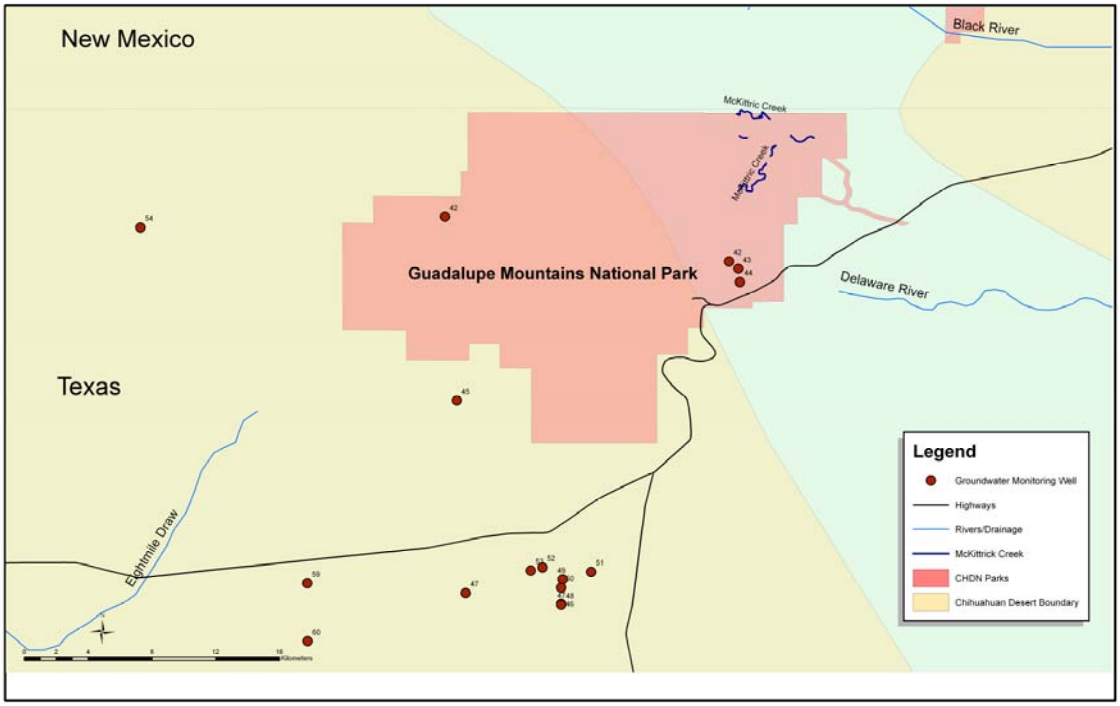

Figure 1.6 Surface-water and groundwater monitoring locations within and near Guadalupe Mountains National Park (location numbers refer to Appendix B).

Established in 1976 under the Wild and Scenic Rivers Act, RIGR (Figure 1.7) includes most of the Rio Grande between AMIS and BIBE (Figure 1.7). Surface-water runoff enters RIGR from both the United States and Mexico. Springs also contribute substantial flow to RIGR. Public access to RIGR is limited due to the remote location of the river.

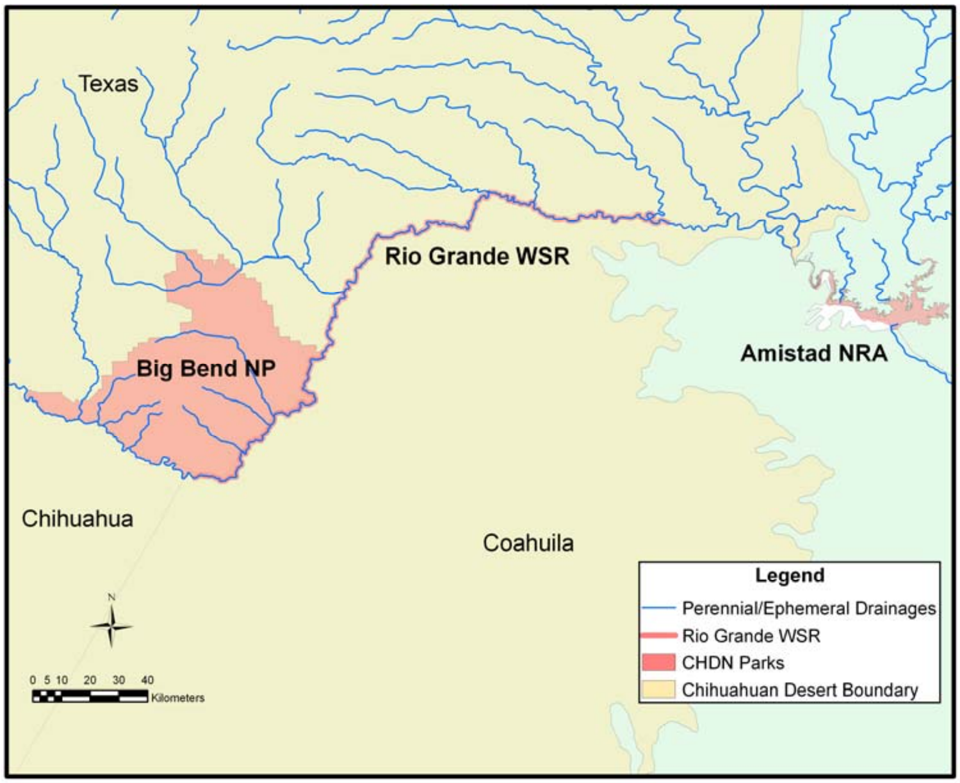

Figure 1.7 The Rio Grande Wild and Scenic River (from Betty Alex, NPS, personal communication, 2005).

Established in 1933, WHSA is embedded within White Sands Missile Range and Holloman Air Force Base. Approximately one-half of the world's largest gypsum dune field is contained within the 58,168 ha (143,733 acres) of WHSA (Figure 1.8). Ephemeral water bodies within WHSA include Lake Lucero and Lost River. No potable groundwater resources exist within WHSA. However, groundwater levels may influence processes that govern the creation and movement of the gypsum dune fields (Almendinger 1971, Almendinger and Titus 1973).

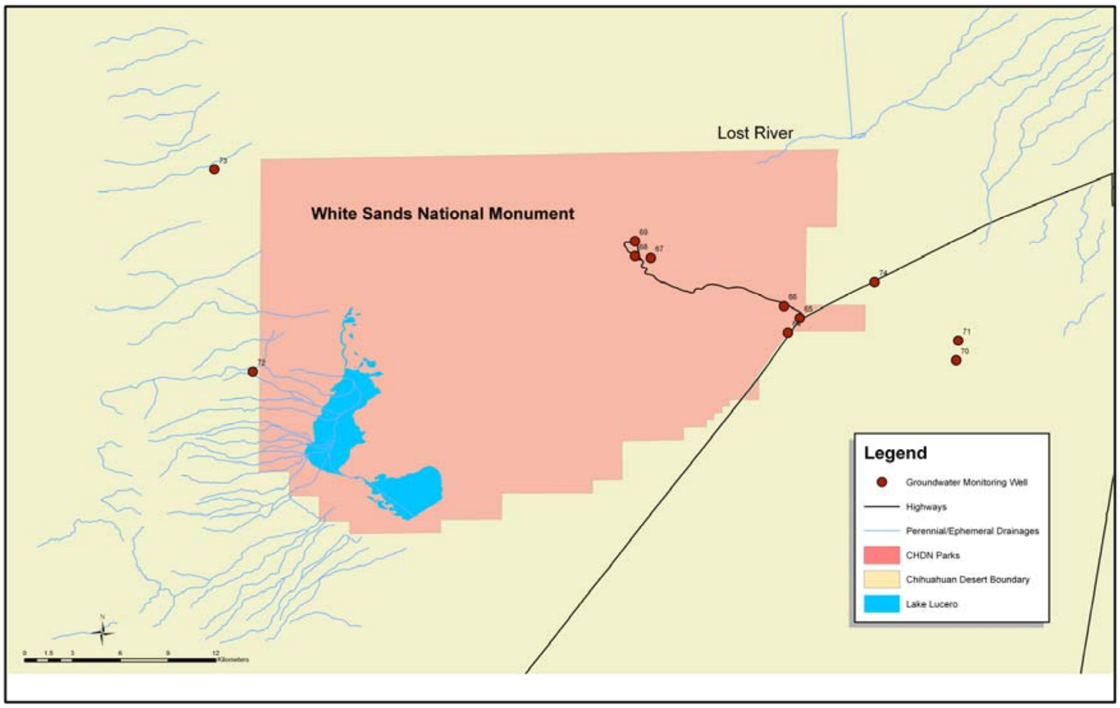

Figure 1.8 Surface-water and groundwater monitoring locations within and near White Sands National Monument (location numbers refer to Appendix B).

1.3 Previous Studies

Reid and Reiser (2005) discuss five water-resource topics within CHDN park units. These are 1) areas of impaired water quality, 2) Outstanding National Resource Waters (ONRW), 3) park waters of special interest, 4) potential threats to park waters, and 5) park-based and park-funded water-quality monitoring. The following sections of the current report summarize their findings and those of other investigations of CHDN water resources.

1.4 Areas of Impaired Water Quality

For the purpose of this report, areas of impaired surface-water quality are those listed in Category 5 under the criteria of Section 303d of the Clean

Water Act (available at http://www.epa.gov/r5water/cwa.htm). Category 5 waters are considered to be impaired with respect to one or more of their designated or existing uses. Current (2006) information about impaired surface waters is available at http://www.nmenv.state.nm.us/wqcc/303d-305b/2004/AppendixB for New Mexico, and http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/04twqi/04_303d.html for Texas. These links contain information about designated or existing water uses and about factors constituting impairment.

No impaired surface waters are listed for CHDN park units within New Mexico. Impaired surface water within the Texas part of the CHDN is limited to Texas stream Segment 2306 (Figure 1.9), which includes parts of the Rio Grande that border BIBE and that comprise the RIGR. Characteristics that qualify for 303d listing in Texas Stream Segment 2306 include chronic toxicity to aquatic organisms, and bacterial concentrations in excess of contact recreation-use standards.

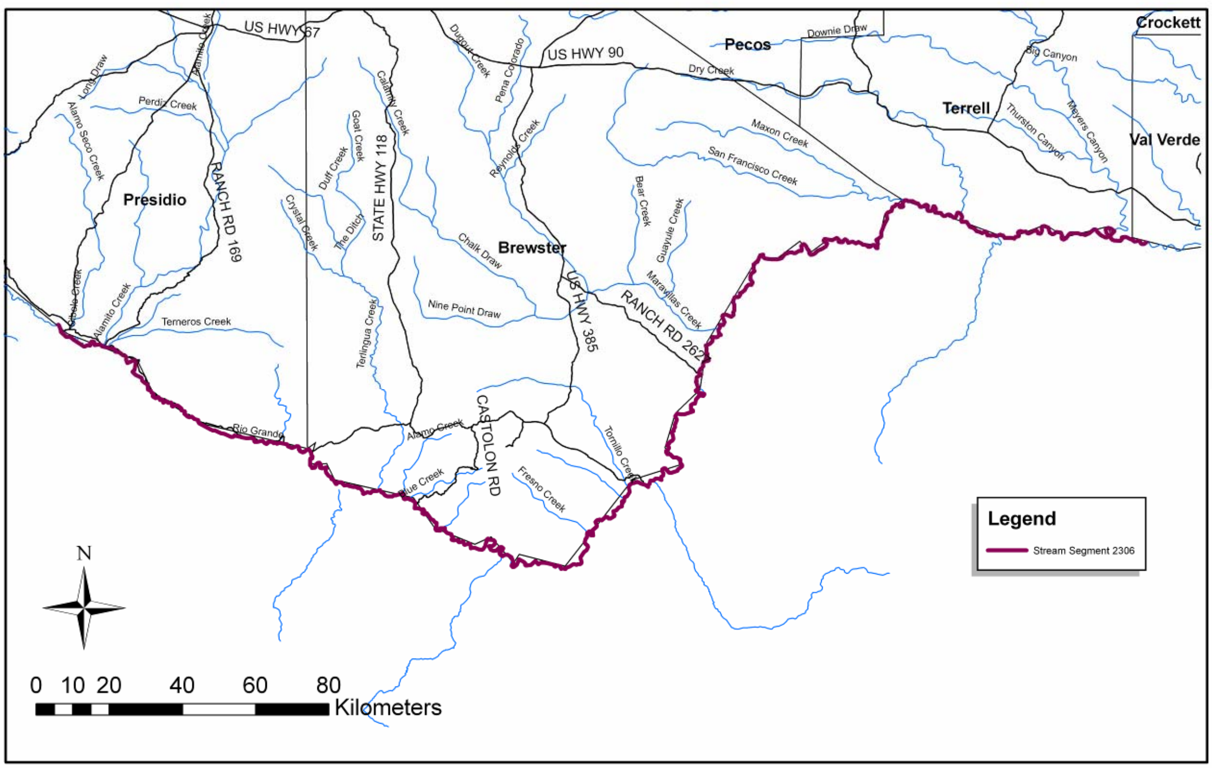

Figure 1.9 Location of Texas Stream Segment 2306 (modified from Texas Commission on Environmental Quality 2002 Water Quality Viewer available at http://gis3.tceq.state.tx.us/website/irwqv2/default.htm).

1.5 Outstanding National Resource Waters

An ONRW has exceptionally good water quality and must be protected from degradation (http://www.epa.gov/owow/wetlands/regs/quality.html). The U.S. Environmental Protection Agency's antidegradation policy provides "for the protection of water quality in high quality waters that constitute an ONRW by prohibiting the lowering of water quality. ONRWs are often regarded as the highest quality waters of the United States. However, ONRW designation also offers special protection for waters of 'exceptional ecological significance.' These are water bodies that are important, unique, or sensitive ecologically, but whose water quality as measured by the traditional parameters such as dissolved oxygen or pH may not be particularly high or whose characteristic cannot be adequately described by these parameters (such as certain wetlands)." No ONRW exist within the CHDN park units.

1.6 Park Waters of Special Interest

The majority of surface waters within CHDN are not classified as impaired. Nevertheless, selected surface-water and groundwater resources are of special interest to the CHDN and individual parks.

The principal surface-water body within AMIS is the International Amistad Reservoir. Therefore, the quantity and quality of water in the reservoir is of great interest to AMIS. Devil's River is the largest stream within AMIS and contains some of the best quality surface water in Texas (Texas Commission on Environmental Quality 2004).

Springs that discharge to the Rio Grande, including Langford Hot Springs Complex and Lower Canyons Thermal Spring Complex, have been designated by BIBE as important for protection. The discharge from Langford Hot Springs Complex lowers the salinity of water in the Rio Grande along Texas Stream Segment 2306 (Figure 1.9). Terlingua Creek within BIBE is designated as an ecologically significant stream segment by the Texas Parks and Wildlife Department (Reid and Reiser 2005). This designation, while providing no additional protection, gives formal recognition to the ecological value of Terlingua Creek.

Rattlesnake Spring, acquired by NPS in 1934 as a source of public water supply, is of special importance to CAVE. Public water supply to CAVE is currently met using groundwater from a well approximately 100 meters from Rattlesnake Spring. This well produces water from the same alluvial aquifer that supplies discharge to Rattlesnake Spring (Gary Rosenlieb, NPS 2006, written communication). Rattlesnake Spring has exceptionally good water quality (New Mexico Environment Department 2003). Rattlesnake Spring was added to the National Register of Historic Places in 1988.

Limpia Creek, which forms the northern boundary of the park, is the only perennial surface-water body associated with FODA. No waters of special interest are present within FODA.

McKittrick Creek and Choza Stream and Springs are exceptional for perennial discharges that support stable riparian ecosystems and are identified as waters of special interest within GUMO. McKittrick Creek is a popular destination for tourists in GUMO.

The entire reach of the RIGR is of special interest to the CHDN. The Texas Parks and Wildlife Department has designated a part of the RIGR (Texas Stream Segment 2306) as an ecologically significant stream (Reid and Reiser 2005).

Lost River and Lake Lucero are waters of special interest to WHSA (Figure 1.8). Lake Lucero occupies the lowest elevations of the Tularosa Basin and is the source of gypsum sand dunes within the park. Lake Lucero receives surface-water runoff from surrounding areas, including White Sands Missile Range. Lost River flows through Holloman Air Force Base across the extreme eastern margin of WHSA and terminates within the dune field. Both Lake Lucero and Lost River are ephemeral.

1.7 Potential threats to park water resources

The following list is a summary of the threats identified in Reid and Reiser (2005) and in other CHDN and park records:

AMIS – Surface-water contamination by sediments, bacteria, and anthropogenic organic compounds transported through surface-water discharge and storm-water runoff;

BIBE – Surface-water contamination by sediments, bacteria, and anthropogenic organic compounds transported by surface-water discharge and storm water runoff, and groundwater contamination by infiltration of anthropogenic organic compounds;

CAVE – Infiltration of anthropogenic organic compounds, introduced at land surface, into caves (van der Heidje et al. 1997), potential contamination of groundwater and surface water by oil and gas activity (Richard 1988a, 1988b, 1989a, 1989b);

FODA – Surface-water and groundwater contamination from surrounding urban sources;

GUMO – Surface-water contamination by bacteria and anthropogenic organic compounds transported through surface-water runoff from camping areas and parking lots, potential changes in quantity and quality of groundwater resources associated with groundwater development and waste disposal in the Salt Basin;

RIGR – Surface-water contamination by sediments, bacteria, and anthropogenic organic compounds through surface-water flow and storm water runoff; and

WHSA – Surface-water and groundwater contamination associated with runoff from, and infiltration through, surrounding military lands; and lowering of groundwater levels associated with regional groundwater development.

Park-based and Park-funded Water-resource Monitoring

Park-based and park-funded monitoring of water resources within the CHDN is described by Reid and Reiser (2005). Park-based and -funded monitoring is summarized below:

AMIS – Cooperation with Texas Commission on Environmental Quality (TCEQ) and the U.S. Geological Survey (USGS) in surface-water quality and quantity monitoring;

BIBE – Monitoring of groundwater levels in selected wells, pumping tests to investigate the interaction between surface water and groundwater; construction of a database containing the location and condition of over 300 springs, seeps and wells; cooperation with USGS in studies of Rio Grande water quality and environmental impacts of mining activities;

CAVE – Monitoring of pool levels in Carlsbad Caverns and Lechuguilla Cave, monitoring of water quality in pools in Carlsbad Caverns;

FODA – No monitoring of park-based water-resources is conducted;

GUMO – Monitoring of water quality at four sites on McKittrick Creek and one site on Choza Spring;

RIGR – No park-based water-resource monitoring is conducted; and

WHSA – Monitoring of groundwater levels in selected wells.

2 Selected Results of Past and Current (2006) Water Quality Monitoring

Long-term monitoring of surface-water and groundwater resources in and near CHDN parks has been undertaken by individual park units within the CHDN, International Boundary and Water Commission (IBWC), New Mexico Office of the State Engineer (NMOSE), TCEQ, Texas Water Development Board (TWDB), and the USGS. Within the Texas part of the CHDN, long- term water-quality monitoring is largely restricted to the Rio Grande and its tributaries. Sites of long-term and current surface -water and groundwater-resources monitoring within and near CHDN parks are shown in Tables A.1 and B.1, and in Figures 1.2 through 1.8.

Texas stream segments identified by Reid and Reiser (2005) as candidates for monitoring by CHDN include

- Stream Segment 2304 – Rio Grande below International Amistad Reservoir (Figure 2.1),
- Stream Segment 2305 - International Amistad Reservoir (Figure 2.2),
- Stream Segment 2306 – Rio Grande above International Amistad Reservoir (Figure 1.9),
- Stream Segment 2309 – Devil's River (Figure 2.3), and
- Stream Segment 2310 – Lower Pecos River (Figure 2.4).

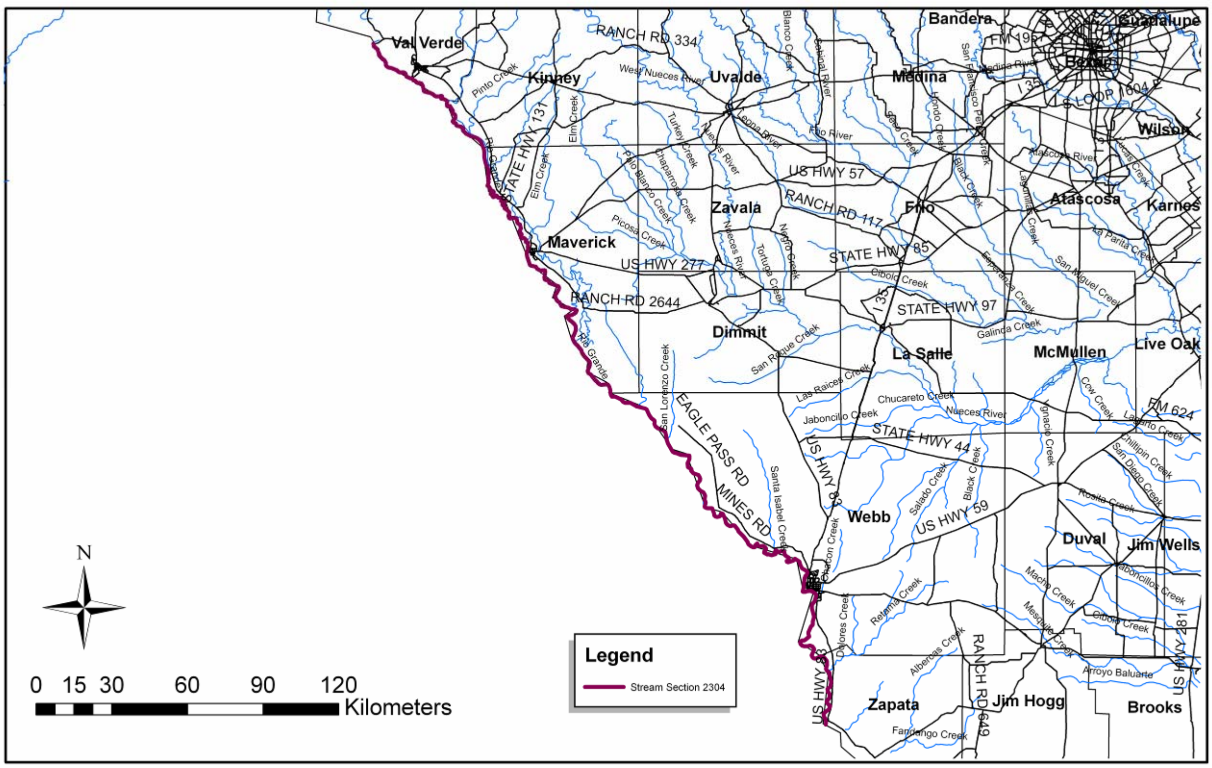

Figure 2.1 Location of Texas Stream Segment 2304 (modified from Texas Commission on Environmental Quality 2002 Water Quality Viewer available at http://gis3.tceq.state.tx.us/website/irwqv2/default.htm).

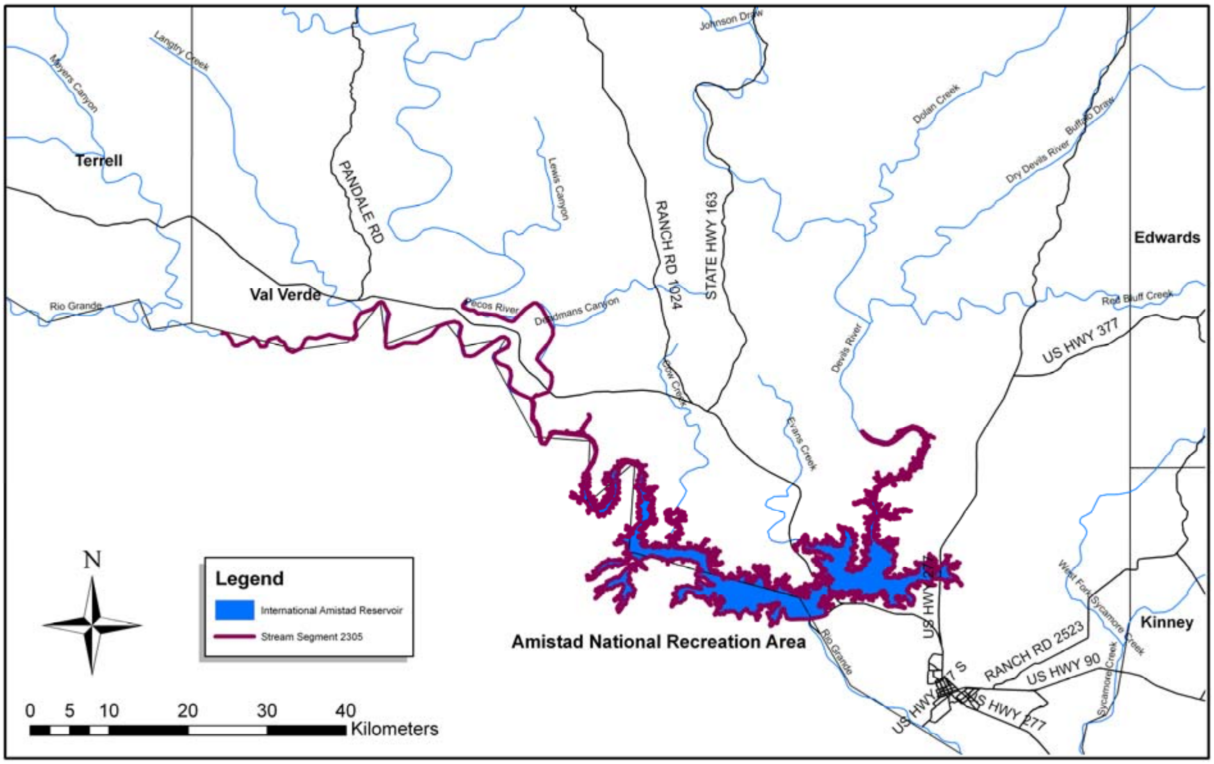

Figure 2.2 Location of Texas Stream Segment 2305 (modified from Texas Commission on Environmental Quality 2002 Water Quality Viewer available at http://gis3.tceq.state.tx.us/website/irwqv2/default.htm).

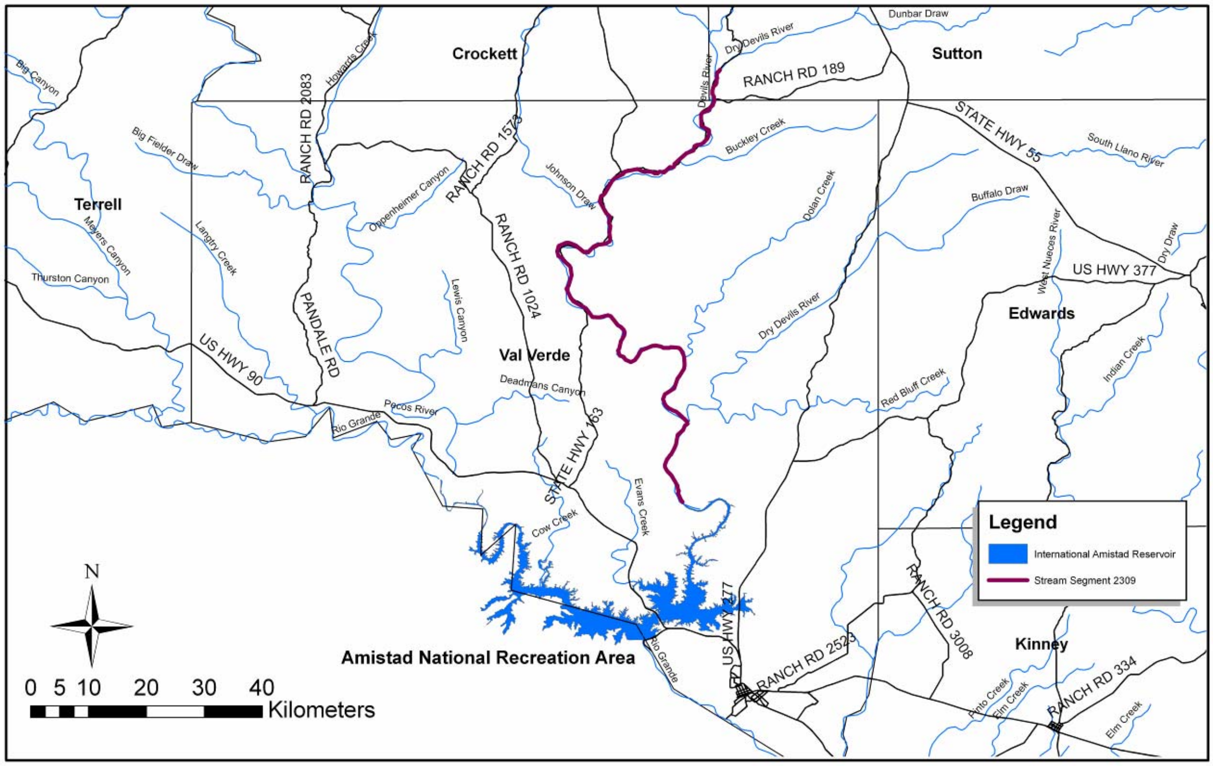

Figure 2.3 Location of Texas Stream Segment 2309 (modified from Texas Commission on Environmental Quality 2002 Water Quality Viewer available at http://gis3.tceq.state.tx.us/website/irwqv2/default.htm).

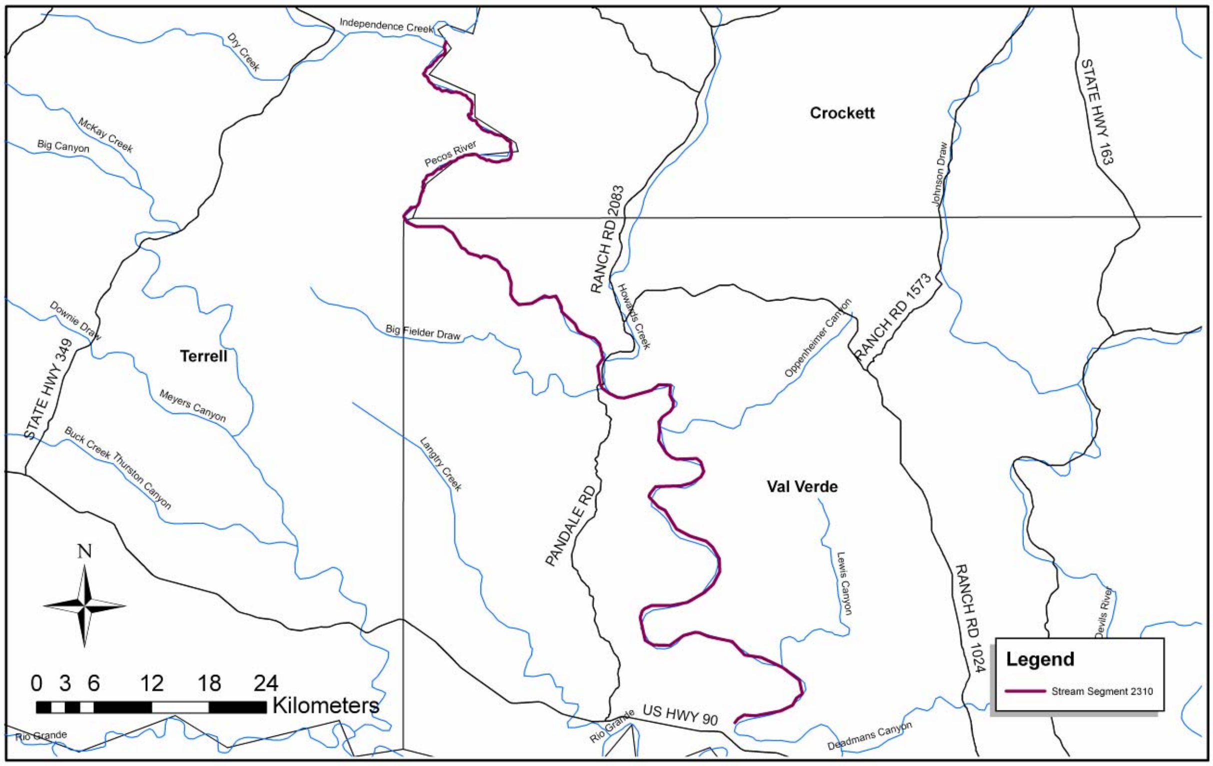

Figure 2.4 Location of Texas Stream Segment 2310 (modified from Texas Commission on Environmental Quality 2002 Water Quality Viewer available at http://gis3.tceq.state.tx.us/website/irwqv2/default.htm).

Additional surface-water resources that may be considered for monitoring by CHDN include Texas Stream Segment 2307 (Rio Grande below Riverside Diversion Dam, Figure 2.5) and reaches of Black River that run through and near CAVE. Monitoring of Texas Stream Segment 2307 would provide information on the quality and quantity of water entering the reach of the Rio Grande along the border of BIBE. State of Texas water-quality criteria for selected stream segments are listed in Table 2.1.

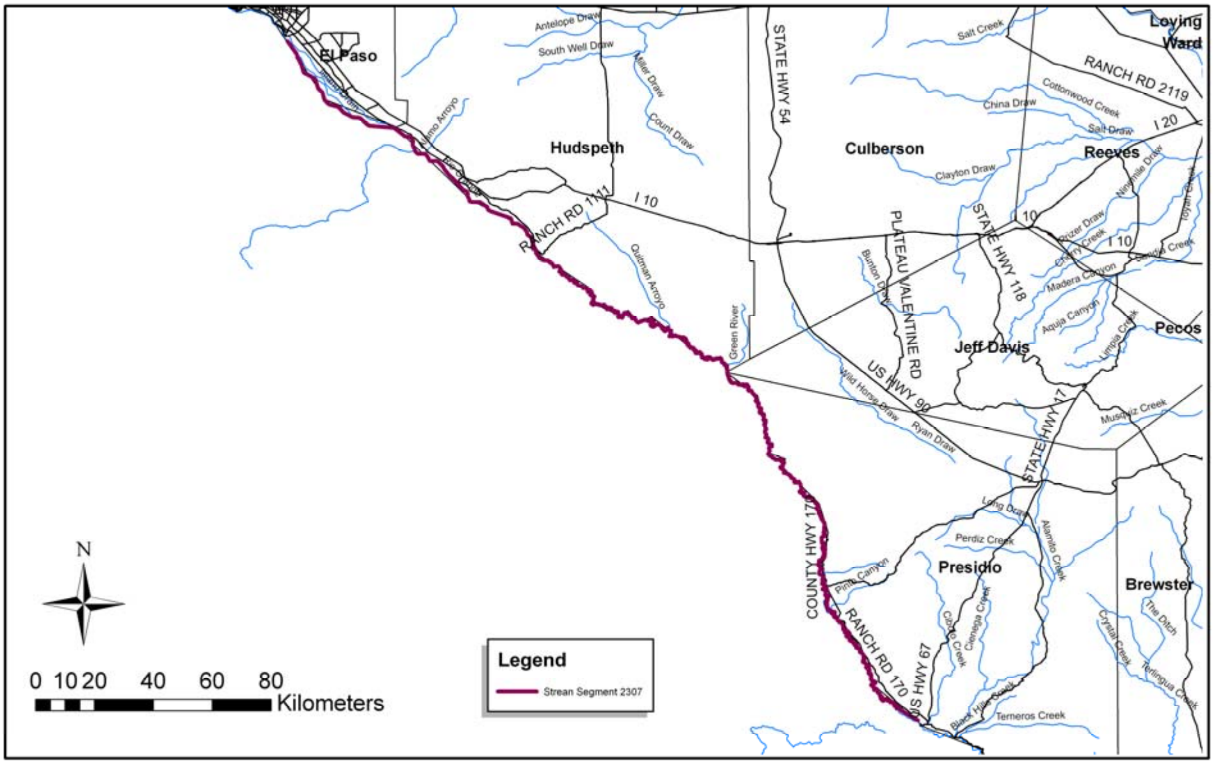

Figure 2.5 Location of Texas Stream Segment 2307 (modified from Texas Commission on Environmental Quality 2002 Water Quality Viewer available at http://gis3.tceq.state.tx.us/website/irwqv2/default.htm).

Table 2.1. Water quality criteria for selected Texas stream segments in the areas of: contact recreation use, aquatic life use, and public supply use as established by the State of Texas (Texas Natural Resources conservation Commission, 2000).

Stream segment number	Chloride, in milligrams per liter	Sulfate, in milligrams per liter	Total dissolved solids, in milli-grams per liter	Dissolved oxygen, in milli-grams per liter	pH range	Indicator bacteria, in colonies per 100 milliliters		Temperature, in degrees Fahrenheit
						Geometric mean	Maximum per sample	
2304	200	300	880	5.0	6.5 - 9.0	126	200	95
2305	150	270	800	5.0	6.5 - 9.0	126	200	88
2306	300	570	1,550	5.0	6.5 - 9.0	126	200	93
2307	300	550	1,550	5.0[1]	6.5 - 9.0	126	200	93
2309	50	50	300	6.0	6.5 - 9.0	126	200	90
2310	1,700	1,000	4,000	5.0	6.5 - 9.0	126	200	92

[1] Criteria applicable to the part of stream segment 2307 containing station 08374200

Results of TCEQ water quality assessments on selected Texas Stream Segments are listed in Table 2.2. These assessments were conducted based on the following criteria: 1) aquatic life; 2) contact recreation; 5) general; 4) fish consumption; 5) public supply; and 6) overall use.

Table 2.2. Water quality assessments on selected Texas stream segments from the Texas Commission on Environmental Quality 2004 (source: http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/04twqi/basins/riogrande.html).

Texas stream segment	Use or area of concern	Status	Parameters assessed
2304	Contact recreation use	Not supporting	Bacteria
2304	Aquatic life use	Partially supporting	Chronic toxicity
2304	Aquatic life use	Concern	Dissolved oxygen
2304	Nutrient enrichment	Concern	Phosphorus
2305	Nutrient enrichment	Concern	Phosphorus
2306	Aquatic life use	Partially supporting	Chronic toxicity
2306	Contact recreation use	Not supporting	Bacteria
2306	Algal growth	Concern	Excessive algal growth
2306	Public supply use	Concern	Chloride, sulfate, dissolved solids
2307	General use	Not supporting	Chloride, dissolved solids, bacteria
2307	Nutrient enrichment	Concern	Phosphorus ammonia
2307	Algal growth	Concern	Excessive algal growth
2307	Public supply use	Concern	Chloride, sulfate, dissolved solids
2310	Public supply use	Concern	Chloride, sulfate, dissolved solids

Areas of impaired water quality include Texas Stream Segment 2304 (chronic toxicity to aquatic life, and bacteria concentrations exceeding those recommended for contact recreation); Texas Stream Segment 2305 (chronic toxicity to aquatic life); and Texas Stream Segment 2307 (chloride, dissolved solids, and bacterial concentrations exceeding those recommended for general use). The status of stream segments identified as 'concern' in Table 2.2 do not rise to the level of impairment required for 303d listing. Other specific areas of concern indicated by TCEQ but not listed in Table 2.2 include Texas Stream Segment 2304 (phosphorus concentration); Texas Stream Segment 2305 (phosphorus concentration); Texas Stream Segment 2306 (excessive algal growth); and Texas Stream Segment 2307 (phosphorus concentration and excessive algal growth).

Statistical summaries of the results of long-term water-quality monitoring by the USGS at stream-gaging stations 08450900 (Texas Stream Segment 2304); 08377200 (Texas Stream Segment 2305); 08374200 (Texas Stream Segment 2307); and 08447410 (Texas Stream Segment 2310) are listed in Tables 2.3 through 2.6.

Table 2.3. Statistical summary of selected water quality data collected at Station 08450900 (Texas stream segment 2304) between 1997 and 2006.

Water Quality Parameter	Number of observations or samples	Minimum value	Maximum value	Percentile				
				5	25	50	75	95
Temperature, in degrees Celsius	57	11.5	26.5	12.5	14.5	18.0	21.0	26.0
pH	57	7.2	8.3	7.3	7.6	7.8	8.0	8.3
Dissolved oxygen, in milligrams per liter	57	1.3	12.3	1.6	4.6	7.1	8.9	10.7
Dissolved chloride, in milligrams per liter	58	60.86	200.0	94.1	123	133.2	157.2	190
Dissolved sulfate, in milligrams per liter	58	93.66	260	142.5	171.4	191.5	220	250.0

Table 2.4. Statistical summary of selected water quality data collected at Station 08377200 (Texas stream segment 2305) between 1996 and 2006.

Water Quality Parameter	Number of observations or samples	Minimum value	Maximum value	Percentile				
				5	25	50	75	95
Temperature, in degrees Celsius	93	9.5	29.0	12.0	17.5	22.5	27.0	28.0
pH	93	7.4	8.5	7.5	7.8	8.0	8.2	8.4
Dissolved oxygen, in milligrams per liter	93	2.6	12.1	4.8	6.8	7.8	9.2	10.7
Dissolved chloride, in milligrams per liter	92	14.37	300.0	27.85	49.75	102.5	202.9	265.7
Dissolved sulfate, in milligrams per liter	92	113.1	520.5	129.4	230.2	289.5	351.7	475.0

Table 2.5. Statistical summary of selected water quality data collected at Station 08374200 (Texas stream segment 2307) between 1999 and 2006.

Water Quality Parameter	Number of observations or samples	Minimum value	Maximum value	Percentile				
				5	25	50	75	95
Temperature, in degrees Celsius	54	8.5	31.5	10	13	22.5	27	29.5
pH	51	7.5	8.5	7.5	7.8	7.9	8.1	8.3
Dissolved oxygen, in milligrams per liter	51	5.6	16.2	6.1	7.1	8.7	10.3	13.9
Dissolved chloride, in milligrams per liter	53	44.05	722.1	101.7	210.1	379.0	517.2	692.3
Dissolved sulfate, in milligrams per liter	53	228.0	1083	394.3	584.0	686.8	776.6	1057

Table 2.6. Statistical summary of selected water quality data collected at Station 08447410 (Texas stream segment 2310) between 1996 and 2006.

Water Quality Parameter	Number of observations or samples	Minimum value	Maximum value	Percentile				
				5	25	50	75	95
Temperature, in degrees Celsius	91	9.8	31.5	11.0	17.0	23.5	28.5	30.5
pH	90	7.5	8.5	7.9	8.0	8.1	8.2	8.4
Dissolved oxygen, in milligrams per liter	91							
Dissolved chloride, in milligrams per liter	88	101.9	1300	399.5	527.4	671.5	816.7	1100
Dissolved sulfate, in milligrams per liter	88	68.07	740.0	251.5	313.6	393.2	491.5	618.3

For stream-gaging station 08450900, dissolved oxygen concentration is less than 5.0 milligrams per liter (mg/L) in at least 25 percent of the recorded data. For stream-gaging station 08377200, dissolved oxygen concentration is less than 5.0 mg/L in at least 5 percent of the recorded data, dissolved chloride concentration is greater than 150 mg/L in at least 25 percent of analyzed samples, and dissolved sulfate concentration is greater than 270 mg/L in at least 50 percent of analyzed samples. For stream-gaging station 08374200, dissolved chloride concentration is greater than 300 mg/L in at least 50 percent of analyzed samples and dissolved sulfate concentration is greater than 550 mg/L in at least 75 percent of analyzed samples. Results reported in this paragraph are those that exceed Texas surface-water quality standards listed in Table 2.1.

3 Vital Signs

Water-resources vital signs include a set of indicators that show the quality and quantity of surface water and groundwater within CHDN park units. The following sections will document the processes and criteria used to identify, prioritize, and select water-resource vital signs and will discuss selected water-resource vital signs that accomplish the goals of inventory and monitoring.

3.1 Selection of Vital Signs

Approaches to identification of water-resource vital signs applicable to CHDN park units included: 1) input from NPS personnel and water-resource experts from government and academe during a vital signs workshop held October 31-November 1, 2005, in Las Cruces, New Mexico; 2) a web-based survey in which workshop invitees ranked lists of water related issues and lists of potential water-resource vital signs prior to the Las Cruces workshop; 3) inclusion of a list of mandatory surface-water quality vital signs (pH, dissolved oxygen concentration, specific conductance, temperature, and discharge) established by NPS; 4) input from water and ecological resources experts from government and academe during a vital signs workshop held June 14-15, 2006, in El Paso, Texas; and 5) review of applicable Federal, New Mexico, and Texas water-quality regulations. Workshop participants are listed in Table 3.1.

Table 3.1. Participants in Chihuahuan Desert Network vital signs workshops.

Participant	Affiliation
October 31-November 1, 2005 Water Quality and Aquatic Resources Workshop held in Las Cruces, New Mexico	
Scott Anderholm	U.S Geological Survey
Monica Barrera	Holloman Air Force Base
Gorden Bell	National Park Service
Jeff Bennett	National Park Service
Paul Burger	National Park Service
David Bustos	National Park Service
Michael Carlson	U.S Geological Survey
Rick Huff	U.S Geological Survey
Phill King	New Mexico State University
Doug McAda	U.S Geological Survey
Seiichi Miyamoto	Texas A&M University
Hildy Reiser	National Park Service
Tom Richie	National Park Service
Mike Roark	U.S Geological Survey
Gary Rosenlieb	National Park Service
Craig Runyan	New Mexico State University
Liz Walsh	University of Texas at El Paso
Diane White	National Park Service
June 14-15, 2006 Vital Signs Prioritization Workshop held in El Paso, Texas	
Bennett, Jeff	National Park Service
Briggs, Mark	Mark Briggs Consulting
Huff, Rick	U.S Geological Survey
Groeger, Al	Texas State University
Keeshen, Rebecca, note taker	University of New Mexico
Lambert, Becky	U.S Geological Survey
Langman, Jeff	U.S Geological Survey
Longley, Glenn	Texas State University
Lougheed, Vanessa	University of Texas at El Paso
Moring, Bruce	U.S Geological Survey
Roemer, Dave	National Park Service
Rosenlieb, Gary	National Park Service
Shanks, W.C. "Pat"	U.S Geological Survey
Slade, Rick	National Park Service

Criteria used to select water-resource vital signs for CHDN park units included: 1) addressing NPS management issues, 2) addressing ecological and water-resource issues, and 3) addressing legal mandates. Furthermore, vital signs must be collectable from, or measurable in, difficult or remote locations and be determinable to acceptable levels of accuracy and precision.

Reid and Reiser (2005) provide a comprehensive listing of Federal (United States and Mexico) regulations regarding water resources. Most Federal regulations applicable to CHDN monitoring are contained in the Clean Water Act (available at http://www.epa.gov/r5water/cwa.htm). State regulations that govern surface-water quality in CHDN park units in New Mexico, (website information current as of January 22, 2007), are available at http://www.epa.gov/waterscience/standards/wqslibrary/nm/nm_6_wqs.pdf. State regulations that govern surface-water quality in CHDN parks units in Texas, (website information current as of November 8, 2005), are available at http://www.epa.gov/waterscience/standards/wqslibrary/tx/index.html. Selected applicable State surface-water quality standards are summarized from Reid and Reiser (2005), as the following:

New Mexico

1. Black River is designated for use as a public water supply and agricultural use, and as habitat for warm-water aquatic life. State surface-water-quality standards applicable to designated uses for Black River (CAVE) include
   a. pH between 6.6 and 9.0 and temperature no greater than 34°C;
   b. monthly geometric mean of coliform bacteria no greater than 200 colonies per 100 milliliter (ml), with no single sample greater than 400 colonies per 100 ml; and
   c. dissolved solids concentration no greater than 8,500 mg/L, sulfate concentration no greater than 2,500 mg/L, and chloride concentration no greater than 3,500 mg/L during periods of discharge greater than 50 cubic feet per second (1.4 cubic meters per second).
2. State surface-water quality standards applicable to ephemeral streams including Lost River in WHSA and ephemeral streams in CAVE include monthly geometric mean of *E. coli* bacteria no greater than 548 colonies per 100 ml with no single sample greater than 2507 colonies per 100 ml.

Texas

Surface-water quality standards applicable to areas within and near CHDN park units are listed by Texas Stream Segment in Table 2.1. Water quality monitoring in the International Amistad Reservoir is beyond the scope of this report.

3.2 Identified Vital Signs

Water-resource vital signs identified by the CHDN include 1) Surface-water quality as determined by temperature, pH, specific conductance, turbidity; abundance of fecal-indicator bacteria; abundance and diversity of macroinvertebrates, and concentrations of common dissolved inorganic constituents; dissolved oxygen, nutrients, and concentrations of selected anthropogenic organic compounds; 2) rates and frequencies of surface-water discharge; 3) lake and reservoir levels (AMIS and WHSA only); 4) sediment load and chemical composition; 5) groundwater quality as determined by temperature, pH, specific conductance; concentrations of common dissolved inorganic constituents; and concentrations of selected anthropogenic organic compounds; and 6) groundwater levels. Not all vital signs are equally applicable to all CHDN park units.

All identified surface-water vital signs are applicable to AMIS surface-water with the exception of the International Amistad Reservoir. (It should be noted that water-quality issues associated with the International Amistad Reservoir are beyond the scope of this report.) Reservoir levels and water quality are currently (2006) monitored by IBWC and TCEQ, respectively (Appendix A). Studies of water and sediment quality within AMIS are currently (2006) being developed with participation from IBWC, NPS, USGS, and TCEQ (Reid and Reiser 2005). Well numbers 7140303, 7140501, and 7140602, located in the Edwards Limestone formation, within AMIS, are screened (Appendix B, Figure 1.2). Inspection of the TWDB database for Val Verde County, Texas (available at http://www.twdb.state.tx.us) shows almost all recorded wells found in the Edwards Limestone formation for the county that are screened. Though groundwater level was not identified as an important vital sign of AMIS, the information contained in Appendix B may be useful if groundwater monitoring is considered in the future.

All identified surface-water vital signs, with the exception of those pertaining to lakes and reservoirs, are applicable to BIBE. A selected number of surface-water monitoring points within and near BIBE are shown in Appendix A and Figure 1.3. Springs and seeps within BIBE contribute substantial recharge to the Rio Grande (Reid and Reiser 2005). Spring discharge is directly related to groundwater levels; Rio Grande water quality is related to the quality of groundwater discharging as spring flow. This relation suggests that monitoring of groundwater quality and levels may be an important part of assessing the condition of the hydrologic system within BIBE.

As previously discussed, Rattlesnake Spring is considered an important water resource within CAVE. All surface-water vital signs, with the exception of those pertaining to sediment load and composition, are applicable to Rattlesnake Spring. Monitoring of Rattlesnake Spring has been implemented intermittently (Appendix A). Reinstatement of continuous monitoring at Rattlesnake Spring would provide information important to ongoing assessment of the condition of the spring. Concern has been expressed by CAVE administrators over the potential impact of oil and gas activity on water quality in Rattlesnake Spring. Continuous monitoring for factors including specific conductance, along with periodic sampling for petroleum hydrocarbons, could provide an early indication of any deterioration in water quality in Rattlesnake Spring. Furthermore, Reid and Reiser (2005) identify a number of additional perennial and ephemeral seeps and springs within CAVE on which periodic measurements of discharge and water quality should be considered.

No known monitoring takes place in the reach of Black River that runs through CAVE. Monitoring of Black River may be beneficial. A number of wells screened in the Capitan Reef exist in and near CAVE (Appendix B, Figure 1.4). Limited water-quality information exists for these wells, but a number of them have a substantial history of water-level measurement. Continued monitoring of groundwater levels in the area of CAVE would contribute to the overall assessment of groundwater conditions and provide warning of water level declines that may affect spring discharge. CAVE is currently monitoring water quality in subterranean pools. Pool monitoring consists of water levels; basic field parameters including pH, temperature, and specific conductance; and selected inorganic constituents (Paul Burger, NPS 2006, oral communication). (Development of vital signs for subterranean pools in CAVE is beyond the scope of this report.)

No substantial ground or surface-water resources are present on FODA. Continued operation of a USGS stream gage on Limpia Creek (Appendix A and B, and Figure 1.5) may be of interest.

McKittrick Creek and Choza Stream and Spring are of particular interest to GUMO. Currently (2006), monitoring on these surface waters is park-based and limited to basic field parameters. All surface-water vital signs, with the exception of those pertaining to sediment load and composition, are applicable to McKittrick Creek and Choza Stream and Spring. Expanding surface-water monitoring to include all applicable vital signs may be beneficial. Increasing the amount of groundwater level and quality monitoring in wells in the Capitan Reef Complex and Salt Basin alluvium may be of interest. However, there is little justification for groundwater monitoring to include anthropogenic organic compounds at this time (Appendix A and B, and Figure 1.6).

All surface-water vital signs are applicable to the Rio Grande and its tributaries within and near RIGR. Groundwater monitoring within and near RIGR does not currently (2006) appear to be a major issue (Appendix A and B, and Figure 1.7).

Water-resource vital signs applicable to WHSA include those involving groundwater monitoring and water levels in Lake Lucero. Lake Lucero contains surface water intermittently throughout the year and is usually inundated during the summer monsoon months. Water depths in Lake Lucero are typically shallow and the actual depth of water in the lake may not be of substantial environmental importance. However, frequency and duration of inundation of Lake Lucero may be important factors in wildlife habitat and in the generation of airborne gypsum that serves as the source of the gypsum dune fields.

Well numbers 324618106105101, 324648106102701, 324712106105901, 324850106153001, 324854106160201, and 324924106160201 (Appendix B, Figure 1.8) are located within the dune fields of WHSA. Sampling of these wells by the USGS in 2000 did not confirm contamination of groundwater by anthropogenic organic compounds. Although periodic water quality sampling may be justifiable, the measurement of groundwater levels may be a more important factor in assessing the condition of the dune fields.

There is little reason to believe that current and anticipated rates of water withdrawal from the Tularosa Basin will affect regional water levels in or near WHSA for the foreseeable future (Huff 2005). However, local water levels within the dune field change in response to environmental factors such as annual rates of precipitation. Currently (2006), the elevations of well numbers 324618106105101, 324648106102701, 324712106105901, 324850106153001, 324854106160201, and 324924106160201 are unknown. If elevations of these wells were determined, water level measurements could be used to determine the generalized direction of groundwater flow within the dune field, as well as local water levels that may affect dune migration and growth.

4 Protocols

Selected protocols, developed and documented by the USGS, for monitoring of water resources are listed in Table 4.1.

Table 4.1 Selected protocols for water resources-related sampling.

Subject or procedure	Protocol reference
Measuring ground-water levels	Lapham and others, 1995
Sampling for ground-water quality	Koterba and others, 1995
Selection of water-quality sampling equipment	U.S. Geological Survey, chapters variously dated
Procedure for collection of water-quality samples	U.S. Geological Survey, chapters variously dated
Processing of water-quality samples	U.S. Geological Survey, chapters variously dated
Measurement of field parameters (temperature, pH, specific conductance, and dissolved oxygen)	U.S. Geological Survey, chapters variously dated
Measurement of biological indicators	U.S. Geological Survey, chapters variously dated
Collection of biological samples	Greeson and others, 1977
Bottom-materials (sediment) sampling	U.S. Geological Survey, chapters variously dated
Continuous water-quality monitoring	Wagner and others, 2006
Stage measurement at stream-gaging stations	Buchanan and Somers, 1968
Discharge ratings at stream-gaging stations	Kennedy, 1984
Computation of stream-flow records	Kennedy, 1983
Determining elevations at stream-gaging stations	Kennedy, 1990
Measurement of fluvial sediment	Edwards and Glysson, 1999
Computation of fluvial sediment discharge	Porterfield, 1972

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Appendix A

Appendix A. Location of, and information on, selected surface-water monitoring sites within and near Chihuahuan Desert Network park units.

Map number	Park unit	Station number	Station operator	Latitude	Longitude	Station description	Years of continuous gage operation	First and last years of water-quality record	Water-quality data collected
1	AMIS	13835	TCEQ	29° 27' 30"	101° 03' 26"	AMISTAD RESERVOIR AT BOUY NUMBER 1	--	1999-2005 (TCEQ)	selected basic water-quality parameters [2], nutrients, inorganics, bacteria, metals
2	AMIS	15340	TCEQ	29° 25' 27"	101° 02' 28"	RIO GRANDE BELOW AMISTAD RESERVOIR	--	1997-current (TCEQ)	selected basic water-quality parameters [2], nutrients, inorganics, bacteria, metals
3	AMIS	15892	TCEQ	29° 37' 31"	101° 15' 04"	AMISTAD RESERVOIR, RIO GRANDE ARM	--	1997-2005 (TCEQ)	selected basic water-quality parameters [2], nutrients, inorganics, bacteria, metals
4	AMIS	15893	TCEQ	29° 36' 05"	100° 58' 34"	AMISTAD RESERVOIR, DEVILS RIVER ARM	--	1997-2005 (TCEQ)	selected basic water-quality parameters [2], nutrients, inorganics, bacteria, metals
5	AMIS	08377200	IBWC	29° 46' 50"	101° 45' 20"	RIO GRANDE AT FOSTER RANCH NEAR LANGTRY, TEXAS	1961-current	1973-current (USGS)	NASQAN parameters [1]
6	AMIS	08447410	IBWC	29° 48' 10"	101° 26' 45"	PECOS RIVER NEAR LANGTRY, TEXAS	1967-current	1971-current (USGS)	NASQAN parameters [1]
7	AMIS	08449000	USGS	29° 57' 48"	101° 08' 42"	DEVILS RIVER NEAR JUNO, TEXAS	1925-1973	1964-1970 (USGS)	selected basic water-quality parameters [2], nutrients, inorganics
8	AMIS	08449400	IBWC	29° 40' 35"	101° 00' 00"	DEVILS RIVER AT PAFFORD CROSSING NEAR COMSTOCK, TEXAS	1900-1914; 1960-current	1973-2006 (TCEQ)	selected basic water-quality parameters [2], nutrients, inorganics, bacteria, metals
9	AMIS	08450800	IBWC	--	--	INTERNATIONAL AMISTAD RESERVOIR STORAGE	1968-current	--	--
10	AMIS	08450900	IBWC	29° 25' 30"	101° 02' 27"	RIO GRANDE BELOW AMISTAD DAM NEAR CD. ACUNA	1954-current	1971-2005 (USGS)	NASQAN parameters [1]
11	AMIS	08451300	IBWC	29° 23' 15"	100° 56' 00"	CANTU SPRING NEAR DEL RIO, TEXAS	1961-current	--	--
12	AMIS	08451500	IBWC	29° 21' 10"	100° 56' 35"	CIENEGAS CREEK NEAR DEL RIO, TEXAS	1965-current	--	--

13	AMIS	08451800	IBWC	29° 20' 07"	100° 55' 41"	RIO GRANDE AT DEL RIO, TEXAS	1923-1941; 1968-current	--	--
14	BIBE/RIGR	08371200	IBWC	30° 10' 30"	104° 41' 10"	RIO GRANDE NEAR CANDELARIA, TEXAS	1975-present	--	--
15	BIBE/RIGR	08371500	IBWC	29° 36' 15"	104° 27' 05"	RIO GRANDE ABOVE RIO CONCHOS NEAR PRESIDIO, TEXAS	1889-current	--	--
16	BIBE/RIGR	08373000	IBWC	29° 34' 57"	104° 25' 52"	RIO CONCHOS NEAR OJINAGA, CHIHUAHUA	1896-1913; 1924-current	--	--
17	BIBE/RIGR	08374000	IBWC	29° 31' 25"	104° 17' 15"	ALAMITO CREEK NEAR PRESIDIO, TEXAS	1932-current	--	--
18	BIBE/RIGR	08374200	IBWC	29° 31' 10"	104° 17' 10"	RIO GRANDE BELOW RIO CONCHOS NEAR PRESIDIO, TEXAS	1955-current	1999-current (USGS)	NASQAN parameters [1]
19	BIBE/RIGR	08374500	IBWC	29° 12' 10"	103° 37' 10"	TERLINGUA CREEK NEAR TERLINGUA, TEXAS	1932-current	--	--
20	BIBE/RIGR	08374550	TCEQ	29° 08' 14"	103° 31' 28"	RIO GRANDE NEAR CASTOLON, TEXAS	2005-current	2005-current (TCEQ)	selected basic water-quality parameters [2], nutrients, inorganics
21	BIBE/RIGR	08375000	IBWC	29° 02' 05"	103° 23' 25"	RIO GRANDE AT JOHNSON RANCH NEAR CASTOLON, TEXAS	1936-current	--	--
22	BIBE/RIGR	08375300	TCEQ	29° 11' 08"	102° 58' 23"	RIO GRANDE AT BIG BEND NATIONAL PARK, TEXAS	2005-current	2005-current (TCEQ)	selected basic water-quality parameters [2]
23	BIBE/RIGR	08376300	USGS	30° 07' 42"	102° 23' 04"	SANDERSON CREEK AT SANDERSON, TEXAS	2003-current	--	--
24	BIBE/RIGR	08450805	IBWC	29° 26' 37"	101° 03' 27"	CARMINA SPRINGS NEAR CD. ACUNA, COAHUILA	1969-current	--	--
25	BIBE/RIGR	08450904	IBWC	29° 25' 20"	101° 02' 40"	SPRING M-15 NEAR CD. ACUNA, COAHUILA	1969-current	--	--
26	BIBE/RIGR	08450905	IBWC	29° 24' 25"	101° 02' 20"	ARROYO DE LOS JABONCILLOS NEAR CD. ACUNA, COAHUILA	1969-current	--	--
27	BIBE/RIGR	08450906	IBWC	29° 25' 20"	101° 02' 35"	SPRING M-5 NEAR CD. ACUNA, COAHUILA	1969-current	--	--

28	BIBE/RIGR	08450910	IBWC	29° 24' 20"	101° 02' 25"	ARROYO DEL BUEY NEAR CD. ACUNA, COAHUILA	1961-current	--	--
29	BIBE/RIGR	08451120	IBWC	29° 24 '00"	101° 01' 55"	MARIS SPRING NEAR CD. ACUNA, COAHUILA	1961-1984; 1985-current	--	--
30	BIBE/RIGR	08451130	IBWC	29° 24' 00"	101° 00' 55"	EIGHT MILE CREEK NEAR DEL RIO, TEXAS	1961-current	--	--
31	BIBE/RIGR	08451140	IBWC	29° 23' 35"	101° 01' 15"	MCKEE SPRING NEAR DEL RIO, TEXAS	1961-current	--	--
32	BIBE/RIGR	08451150	IBWC	29° 22' 35"	101° 01' 15"	ARROYO DE LA TREINTA Y UNA NEAR CD. ACUNA, COAHUILA	1961-current	--	--
33	CAVE	08405300	USGS	32° 06' 36"	104° 28' 17"	RATTLESNAKE SPRING NEAR WHITES CITY, NM	1961-1962	--	--
34	CAVE	08405301	USGS	32° 06' 32"	104° 28' 17"	RATTLESNAKE SPRING EAST NEAR WHITES CITY, NM	2003-2004	--	--
35	CAVE	08405303	USGS	32° 06' 38"	104° 28' 16"	RATTLESNAKE SPRING NORTH NEAR WHITES CITY, NM	2003-2004	--	--
36	FODO	08431700	USGS	30° 36' 48"	104° 00' 04"	LINPIA CREEK ABOVE FORT DAVIS, TEXAS	1965-current	1967-1986 (USGS)	NASQAN parameters [1]

Appendix B

Appendix B. Location of and information on selected groundwater monitoring sites within and near Chihuahuan Desert Network.

Map number	Park unit	Well number	Data source	Aquifer	Latitude	Longitude	First and last years of water-level record	First and last years of water-quality record	Water-quality parameters	Additional information
1	AMIS	5455904	TWDB	Edwards Limestone	30° 07' 57"	101° 09' 34"	2004-2004	1999-2004	temperature, specific conductance, pH, major inorganics	Nature Conservancy

2	AMIS	7112503	TWDB	Edwards Limestone	29^{o} 48' 51"	101^{o} 34' 05"	1967-1968	--	--	Texas Highway Department
3	AMIS	7122403	TWDB	Edwards Limestone	29^{o} 42' 06"	101^{o} 21' 54"	--	1994-1994	temperature, specific conductance, pH, major inorganics	National Park Service
4	AMIS	7122501	TWDB	Edwards Limestone	29^{o} 42' 16"	101^{o} 19' 27"	1977-2003	1977-2003	temperature, specific conductance, pH, major inorganics	Texas Parks and Wildlife
5	AMIS	7123506	TWDB	Edwards Limestone	29^{o} 41' 51"	101^{o} 11' 10"	1990-1990	1997-1997	temperature, specific conductance, pH, major inorganics	Val Verde County Water Conservation District
6	AMIS	7140302	TWDB	Edwards Limestone	29^{o} 27' 59"	101^{o} 01' 21"	1962-1964	1967-1967	temperature, specific conductance, pH, major inorganics	IBWC
7	AMIS	7140303	TWDB	Edwards Limestone	29^{o} 28' 10"	101^{o} 01' 03"	1964-1969	1964-1969	temperature, specific conductance, pH, major inorganics	National Park Service, Public supply
8	AMIS	7140501	TWDB	Edwards Limestone	29^{o} 27' 03"	101^{o} 03' 12"	1964-1964	1964-1964	temperature, specific conductance, pH, major inorganics	IBWC
9	AMIS	7140602	TWDB	Edwards Limestone	29^{o} 27' 29"	101^{o} 01' 46"	1966-1993	1993-1993	temperature, specific conductance, pH, major inorganics	IBWC
10	BIBE	7249401	TWDB	Santa Elena Limestone	29^{o} 10' 52"	102^{o} 59' 32"	--	1994-1998	temperature, specific conductance, pH, major inorganics	Hot Springs
11	BIBE	7249501	TWDB	Edwards-Trinity	29^{o} 10' 56"	102^{o} 57' 09"	--	1987-2003	temperature, specific conductance, pH, major inorganics	Gambusia Spring
12	BIBE	7249503	TWDB	Upper Cretaceous	29^{o} 10' 55"	102^{o} 57' 12"	--	1977-1994	temperature, specific conductance, pH, major inorganics	Spring #4
13	BIBE	7346701	TWDB	Tertiary Volcanics	29^{o} 16' 56"	103^{o} 20' 12"	--	1954-1994	temperature, specific conductance, pH, major inorganics	Oak Spring
14	BIBE	7346702	TWDB	Tertiary Volcanics	29^{o} 17' 28"	103^{o} 20' 12"	1989-1989	--	--	Oak Springs #1 (USBOR)
15	BIBE	7346703	TWDB	Tertiary Volcanics	29^{o} 17' 27"	103^{o} 20' 03"	1989-1989	--	--	Oak Springs #2 (USBOR)
16	BIBE	7346704	TWDB	Upper Cretaceous	29^{o} 16' 25"	103^{o} 20' 07"	--	1954-1989	temperature, specific conductance, pH, major inorganics	Previous well 7346702 - Cattail Falls Spring

17	BIBE	7346803	TWDB	Alluvium	29° 16' 44"	103° 18' 08"	--	1961-1987	temperature, specific conductance, pH, major inorganics	CCC - Lower well
18	BIBE	7346804	TWDB	Alluvium	29° 16' 48"	103° 19' 46"	--	1972-1987	temperature, specific conductance, pH, major inorganics	Window Spring
19	BIBE	7347401	TWDB	Alluvium and Cretaceous	29° 19' 12"	103° 12' 44"	1979-1985	1973-1994	temperature, specific conductance, pH, major inorganics	Panther Junction #4
20	BIBE	7347501	TWDB	Upper Cretaceous	29° 19' 43"	103° 11' 57"	--	--	--	--
21	BIBE	7347504	TWDB	Upper Cretaceous	29° 18' 26"	103° 10' 57"	1979-1984	1977-1994	temperature, specific conductance, pH, major inorganics	K-Bar-2
22	BIBE	7347505	TWDB	Upper Cretaceous	29° 18' 09"	103° 10' 41"	1979-1979	1977-1987	temperature, specific conductance, pH, major inorganics	K-Bar-5
23	BIBE	7352901	TWDB	Rio Grande Alluvium	29° 08' 01"	103° 30' 56"	--	1980-1982	temperature, specific conductance, pH, major inorganics	Castolon Station
24	BIBE	7352902	TWDB	Rio Grande Alluvium	29° 08' 19"	103° 31' 26"	--	1987-1994	temperature, specific conductance, pH, major inorganics	Cottonwood #1
25	BIBE	7352903	TWDB	Alluvium and Cretaceous	29° 08' 24"	103° 31' 25"	--	1977-1977	major inorganics	Castolon Maintenance well
26	BIBE	7352904	TWDB	Alluvium and Cretaceous	29° 08' 52"	103° 30' 32"	1979-1979	1979-1979	temperature, specific conductance, pH, major inorganics	New Castolon well
27	BIBE	7352905	TWDB	Rio Grande Alluvium	29° 08' 20"	103° 31' 30"	1985-1985	1987-1994	temperature, specific conductance, pH, major inorganics	Cottonwood #2
29	BIBE	7352906	TWDB	Rio Grande Alluvium	29° 08' 23"	103° 31' 23"	--	1987-1994	temperature, specific conductance, pH, major inorganics	Cottonwood #3
29	CAVE	321741104204901	USGS	Capitan Reef	32° 17' 41"	104° 20' 49"	1963-1999	--	--	Site number 23S.25E.24.21433
30	CAVE	322235104191001	USGS	Capitan Reef	32° 22' 35"	104° 19' 10"	1947-1998	--	--	Site number 22S.26E.20.31412
31	CAVE	322329104161801	USGS	Capitan Reef	32° 23' 29"	104° 16' 18"	1955-1998	--	--	Site number 22S.26E.15.42200

32	CAVE	322330104155301	USGS	Capitan Reef	32^o 23' 30"	104^o 15' 53"	1947-2003	--	--	Site number 22S.26E.14.322331
33	CAVE	322411104145401	USGS	Capitan Reef	32^o 24' 11"	104^o 14' 54"	1954-2003	--	--	Site number 22S.26E.12.341421
34	CAVE	322456104164901	USGS	Capitan Reef	32^o 24' 56"	104^o 16' 49"	1953-2003	--	--	Site number 22S.26E.03.344441
35	CAVE	C-00509	NMOSE	--	32^o 05' 37"	104^o 29' 39"	1954-1954	--	--	domestic well
36	CAVE	C-00860	NMOSE	--	32^o 11' 17"	104^o 21' 27"	1958-1958	--	--	domestic well
37	CAVE	C-01367	NMOSE	--	32^o 06' 30"	104^o 27' 36"	1967-1967	--	--	domestic well
38	CAVE	C-01546	NMOSE	--	32^o 09' 59"	104^o 22' 29"	--	--	--	domestic well
39	CAVE	C-02047	NMOSE	--	32^o 07' 23"	104^o 28' 38"	--	--	--	livestock well
40	CAVE	C-02236	NMOSE	--	32^o 06' 30"	104^o 27' 05"	1992-1992	--	--	livestock well
41	CAVE	C-02815	NMOSE	--	32^o 07' 09"	104^o 30' 57"	--	--	--	livestock well
42	GUMO	4701401	TWDB	Quaternary Alluvium	31^o 56' 39"	104^o 58' 02"	1948-1948	--	--	--
43	GUMO	4702501	TWDB	Capitan Reef Complex	31^o 55' 08"	104^o 48' 25"	--	--	--	Smith Spring
44	GUMO	4702801	TWDB	Capitan Reef Complex	31^o 54' 53"	104^o 48' 06"	1973-1974	1973-1974	temperature, specific conductance, pH, major inorganics	--
45	GUMO	4702802	TWDB	Capitan Reef Complex	31^o 54' 26"	104^o 48' 03"	--	1995-1999	temperature, specific conductance, pH, major inorganics	--
46	GUMO	4709101	TWDB	Quaternary Alluvium	31^o 50' 25"	104^o 57' 38"	1949-1949	--	--	--

47	GUMO	4717217	TWDB	Quaternary Alluvium	31° 43' 54"	104° 57' 20"	1972-1972	--	--	Former well number 4717102
48	GUMO	4717301	TWDB	Capitan Reef Complex	31° 43' 32"	104° 54' 06"	1960-1993	1960-1963	temperature, specific conductance, pH, major inorganics	Armstrong Farms
49	GUMO	4717302	TWDB	Capitan Reef Complex	31° 43' 31"	104° 54' 06"	1958-2006	1964-2003	temperature, specific conductance, pH, major inorganics	Armstrong Farms
50	GUMO	4717303	TWDB	Capitan Reef Complex	31° 43' 30"	104° 54' 06"	1959-1993	1992-1992	temperature, specific conductance, pH, major inorganics	Armstrong Farms
51	GUMO	4717304	TWDB	Capitan Reef Complex	31° 44' 22"	104° 54' 03"	1965-2003	1965-1965	temperature, specific conductance, pH, major inorganics	--
52	GUMO	4717307	TWDB	Capitan Reef Complex	31° 44' 05"	104° 54' 06"	1965-1994	1965-1965	temperature, specific conductance, pH, major inorganics	--
53	GUMO	4717312	TWDB	Capitan Reef Complex	31° 44' 37"	104° 53' 05"	1965-1965	1965-1965	temperature, specific conductance, pH, major inorganics	--
54	GUMO	4717315	TWDB	Capitan Reef Complex	31° 44' 46"	104° 54' 44"	1965-1965	1965-1965	temperature, specific conductance, pH, major inorganics	--
55	GUMO	4717317	TWDB	Capitan Reef Complex	31° 44' 37"	104° 54' 59"	1965-2000	1965-1968	temperature, specific conductance, pH, major inorganics	--
56	GUMO	4743601	TWDB	Capitan Reef Complex	31° 17' 35"	104° 38' 38"	1965-1972	1971-1971	temperature, specific conductance, pH, major inorganics	--
57	GUMO	4744701	TWDB	Capitan Reef Complex	31° 15' 21"	104° 36' 03"	1970-1972	--	--	Apache Ranch
58	GUMO	4807610	TWDB	Quaternary Alluvium	31° 56' 17"	105° 08' 21"	1948-1951	--	--	--
59	GUMO	4824201	TWDB	Quaternary Alluvium	31° 44' 14"	105° 02' 42"	1965-1965	1972-1972	temperature, specific conductance, pH, major inorganics	--
60	GUMO	4824501	TWDB	Quaternary Alluvium	31° 42' 16"	105° 02' 41"	1972-1972	--	--	--
61	GUMO	4824901	TWDB	Quaternary Alluvium	31° 38' 55"	105° 00' 22"	1965-1965	--	--	--

62	GUMO	4850309	TWDB	Quaternary Alluvium	31° 14' 31"	105° 47' 23"	--	--	--	Esperanza Fresh Water Supply District 1 Well 4
63	GUMO	4850310	TWDB	Quaternary Alluvium	31° 14' 38"	105° 47' 24"	--	--	--	Esperanza Fresh Water Supply District 1 Well 5
64	WHSA	324618106105101	USGS	Tertiary Basin Fill	32° 46' 18"	106° 10' 51"	2000-2000	2000-2000	temperature, specific conductance, pH, major inorganics, organics	WHSA Monitor well number 5
65	WHSA	324648106102701	USGS	Tertiary Basin Fill	32° 46' 48"	106° 10' 27"	2000-2000	2000-2000	temperature, specific conductance, pH, major inorganics, organics	WHSA Monitor well number 4
66	WHSA	324712106105901	USGS	Tertiary Basin Fill	32° 47' 12"	106° 10' 59"	2000-2000	2000-2000	temperature, specific conductance, pH, major inorganics, organics	WHSA Monitor well number 3
67	WHSA	324850106153001	USGS	Tertiary Basin Fill	32° 48' 50"	106° 15' 30"	2000-2000	2000-2000	temperature, specific conductance, pH, major inorganics, organics	WHSA Monitor well number 6
68	WHSA	324854106160201	USGS	Tertiary Basin Fill	32° 48' 54"	106° 16' 02"	2000-2000	2000-2000	temperature, specific conductance, pH, major inorganics, organics	WHSA Monitor well number 2
69	WHSA	324924106160201	USGS	Tertiary Basin Fill	32° 49' 24"	106° 16' 02"	2000-2000	2000-2000	temperature, specific conductance, pH, major inorganics, organics	WHSA Monitor well number 1
70	WHSA	T-00227	NMOSE	Tertiary Basin Fill	32° 45' 22"	106° 05' 09"	--	--	--	White Sands Ranch
71	WHSA	T-00228	NMOSE	Tertiary Basin Fill	32° 46' 02"	106° 05' 06"	1936-1937	--	--	White Sands Ranch
72	WHSA	T-00613	NMOSE	Tertiary Basin Fill	32° 44' 59"	106° 28' 59"	--	--	--	WHSA monitor well
73	WHSA	T-02073	NMOSE	Tertiary Basin Fill	32° 51' 50"	106° 30' 17"	1967-1967	--	--	domestic well
74	WHSA	T-02758	NMOSE	Tertiary Basin Fill	32° 48' 01"	106° 07' 55"	--	--	--	industrial supply